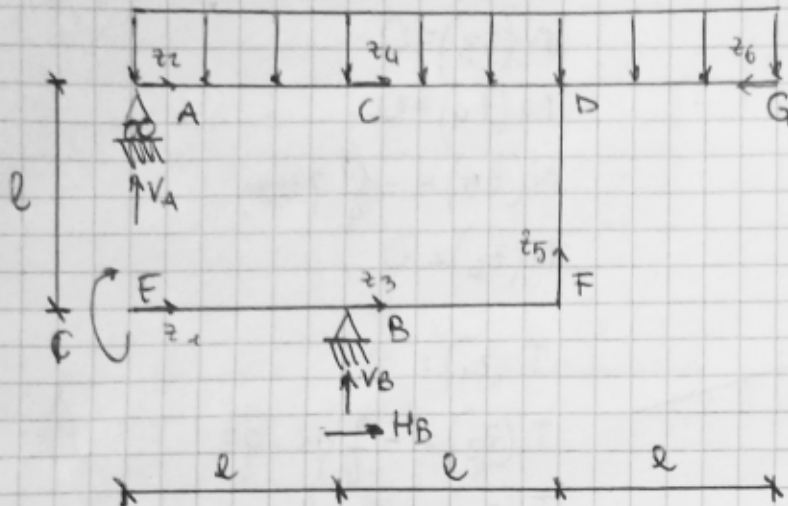


1)

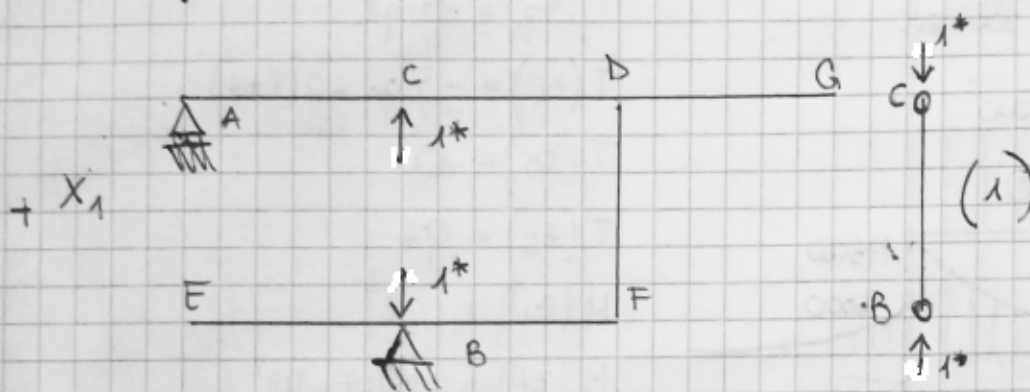


$$q = 2000 \text{ N/m}$$

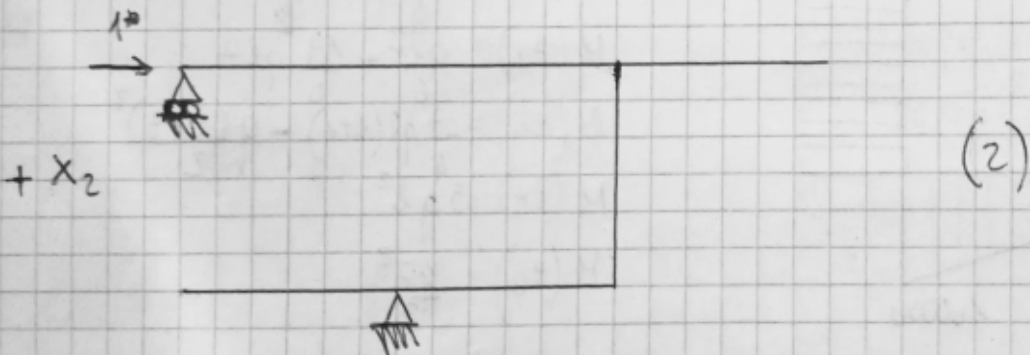
$$L = 4 \text{ m}$$

$$C = \frac{ql^2}{4}$$

(0)

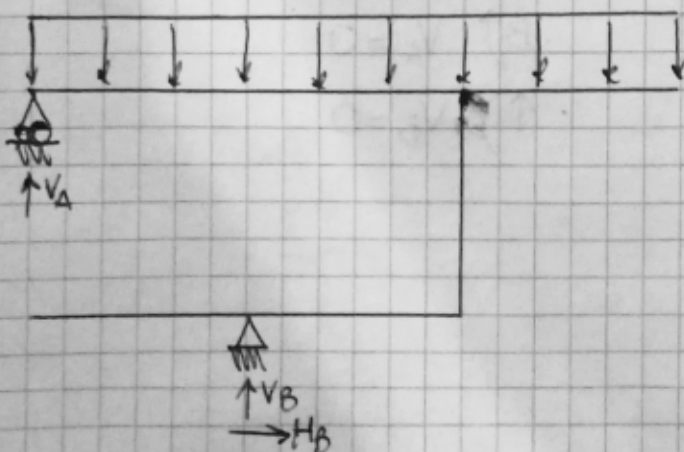


(1)



(2)

SISTEMA (0)



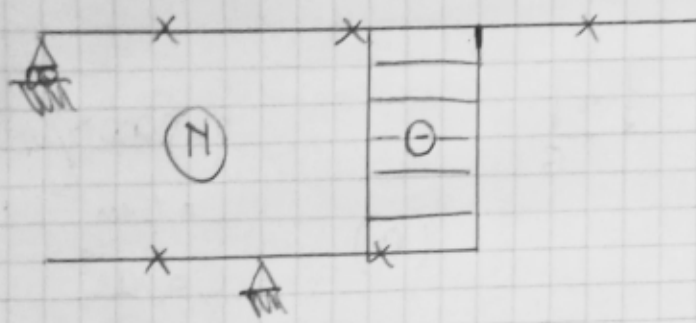
$$\rightarrow) H_B = 0$$

$$A) V_B \cdot l - \frac{q(3l)^2}{2} - \frac{ql^2}{4} = 0$$

$$V_B = \frac{19}{4} ql$$

$$\uparrow) -3ql + \frac{19}{4} ql + V_A = 0$$

$$V_A = -\frac{7}{4} ql$$



$$N(z_1) = 0$$

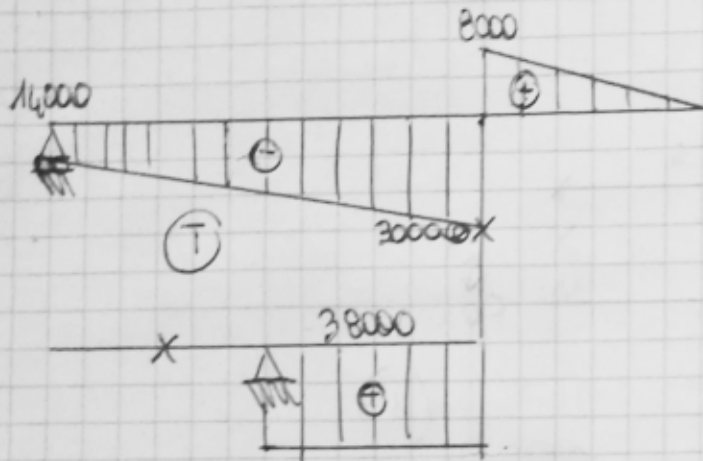
$$N(z_2) = 0$$

$$N(z_3) = 0$$

$$N(z_4) = 0$$

$$N(z_5) = -\frac{19}{4}ql$$

$$N(z_6) = 0$$



$$T(z_1) = 0$$

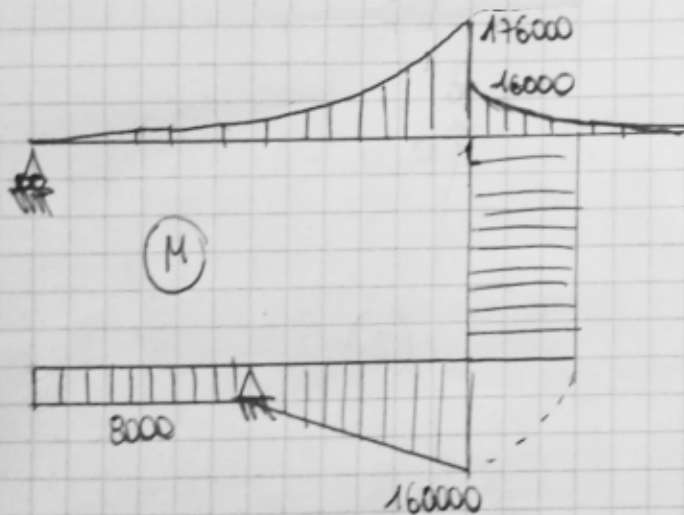
$$T(z_2) = -\frac{7}{4}ql - qz$$

$$T(z_3) = \frac{19}{4}ql$$

$$T(z_4) = -\frac{7}{4}ql - q(l+z)$$

$$T(z_5) = 0$$

$$T(z_6) = ql$$



$$M(z_1) = \frac{ql^2}{2}$$

$$M(z_2) = -\frac{7}{4}qlz - \frac{qz^2}{2}$$

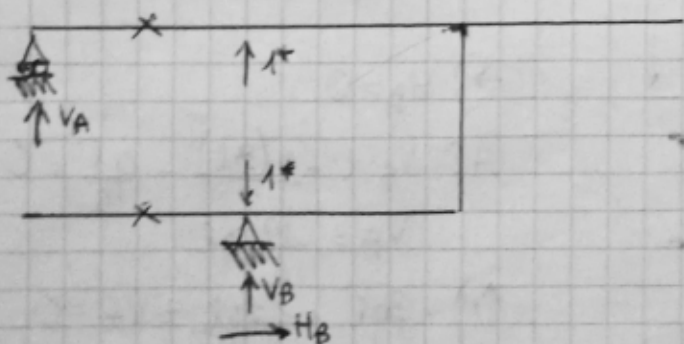
$$M(z_3) = \frac{ql^2}{4} + \frac{19}{4}qlz$$

$$M(z_4) = -\frac{7}{4}ql(l+z) - \frac{q(l+z)^2}{2}$$

$$M(z_5) = \frac{4}{5}ql^2$$

$$M(z_6) = \frac{ql^2}{2}$$

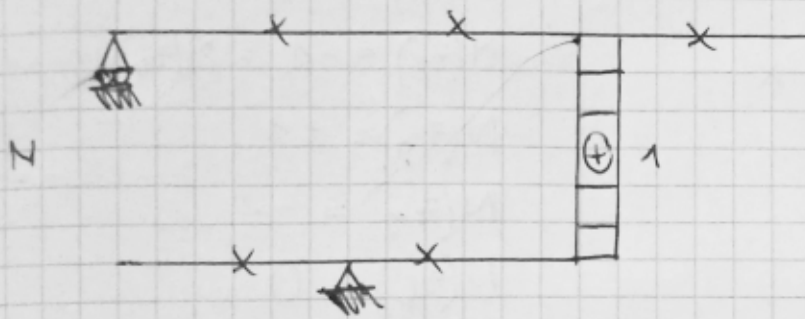
SISTEMA (1)



$$\rightarrow H_B = 0$$

$$B \uparrow V_A = 0$$

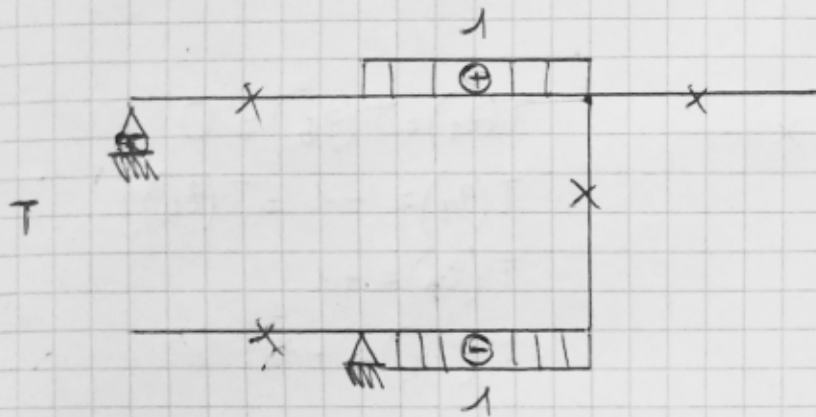
$$\uparrow V_B = 0$$



$$N(z_1) = N(z_2) = N(z_3) = N(z_4) = 0$$

$$N(z_5) = 1$$

$$N(z_6) = 0$$

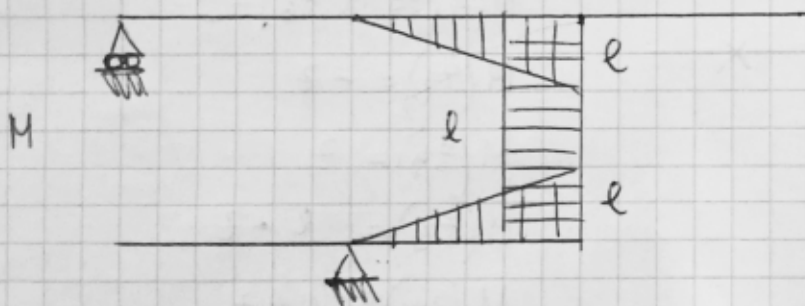


$$T(z_1) = T(z_2) = 0$$

$$T(z_3) = -1$$

$$T(z_4) = 1$$

$$T(z_5) = T(z_6) = 0$$



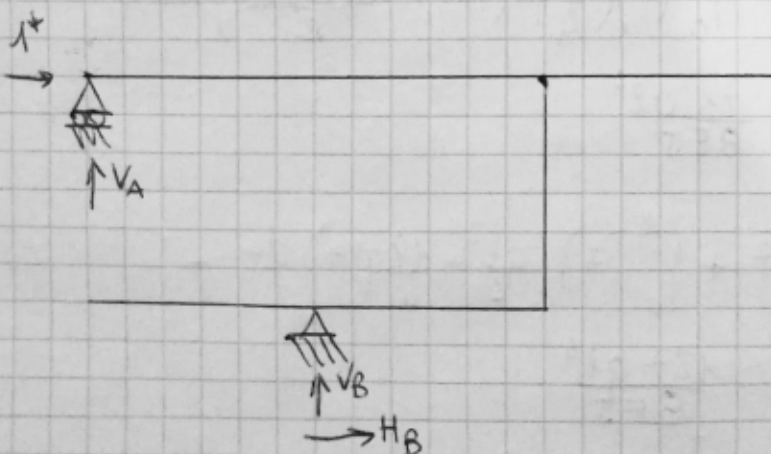
$$M(z_1) = M(z_2) = 0$$

$$M(z_3) = -l$$

$$M(z_4) = l$$

$$M(z_5) = -l$$

SISTEMA (2)

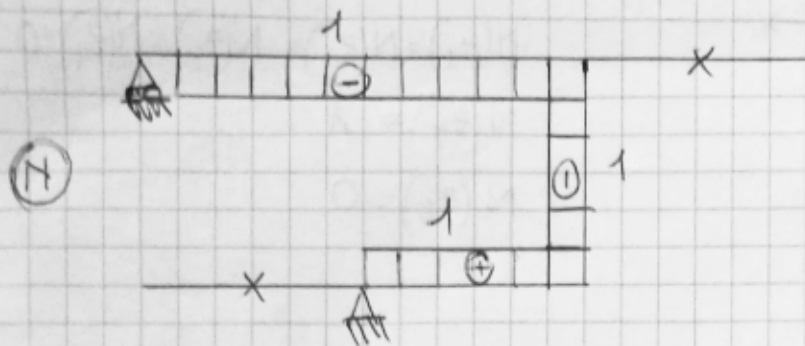


$$\rightarrow H_B = -1$$

$$\uparrow B) -1 \cdot l - V_A \cdot l = 0$$

$$V_A = -1$$

$$\uparrow) V_B = 1^*$$



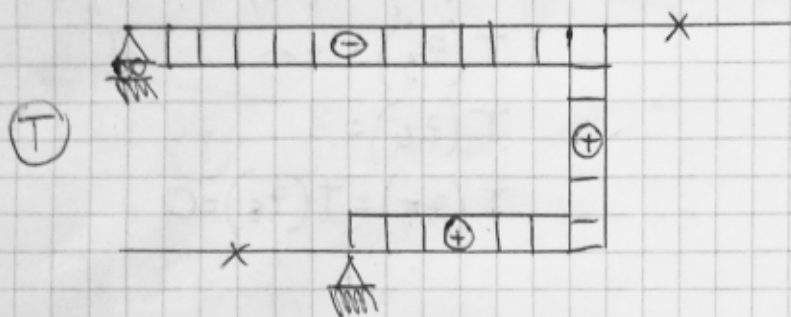
$$N(z_1) = 0$$

$$N(z_2) = -1 = N(z_4)$$

$$N(z_3) = +1$$

$$N(z_5) = -1$$

$$N(z_6) = 0$$

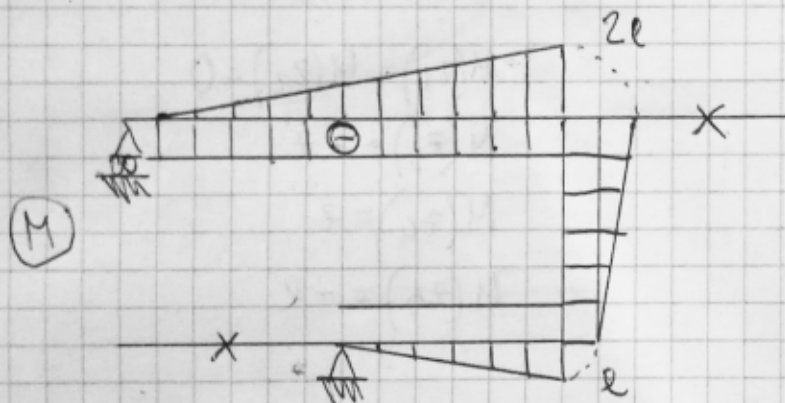


$$T(z_1) = T(z_6) = 0$$

$$T(z_2) = -1 = T(z_4)$$

$$T(z_3) = +1$$

$$T(z_5) = +1$$



$$M(z_1) = M(z_6) = 0$$

$$M(z_2) = -z$$

$$M(z_3) = z$$

$$M(z_4) = -l - z$$

$$M(z_5) = l + z$$

$$M_{10} = \frac{1}{EI} \left[\int_0^l (-z) \left(\frac{ql^2}{4} + \frac{19qlz}{4} \right) dz + \int_0^l (z) \left(-\frac{7ql}{4}(l+z) - \frac{q(l+z)^2}{2} \right) dz + \int_0^l (-l) (5ql) dz \right] = -\frac{71ql^4}{8EI}$$

$$M_{20} = \frac{1}{EI} \left[\int_0^{2l} (-z) \left(-\frac{7qlz}{4} - \frac{qz^2}{2} \right) dz + \int_0^l (z) \left(\frac{ql^2}{4} + \frac{19qlz}{4} \right) dz + \int_0^l (l+z) (5ql) dz \right] = \frac{127ql^4}{8EI}$$

$$M_{11} = \frac{1}{EI} \left[2 \int_0^l z^2 dz + \int_0^l l^2 dz \right] = \frac{5l^3}{3EI}$$

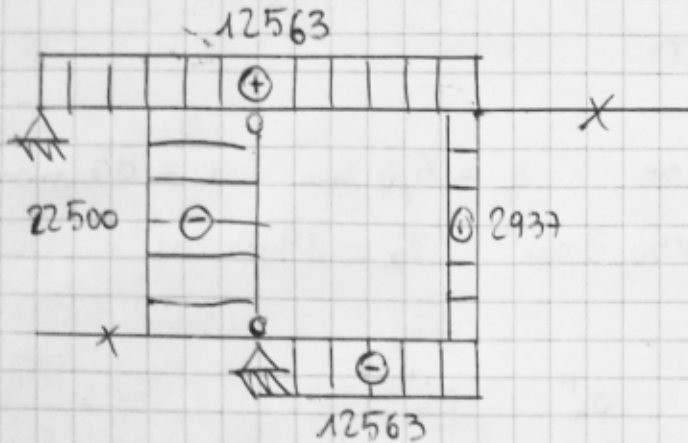
$$M_{22} = \frac{1}{EI} \left[\int_0^{2l} z^2 dz + \int_0^l z^2 dz + \int_0^l (l+z)^2 dz \right] = \frac{16l^3}{3EI}$$

$$M_{12} = \frac{1}{EI} \left[\int_0^l -z^2 dz + \int_0^l (-l-z)(z) dz + \int_0^l (l+z)(-l) dz \right] = -\frac{8l^3}{3EI}$$

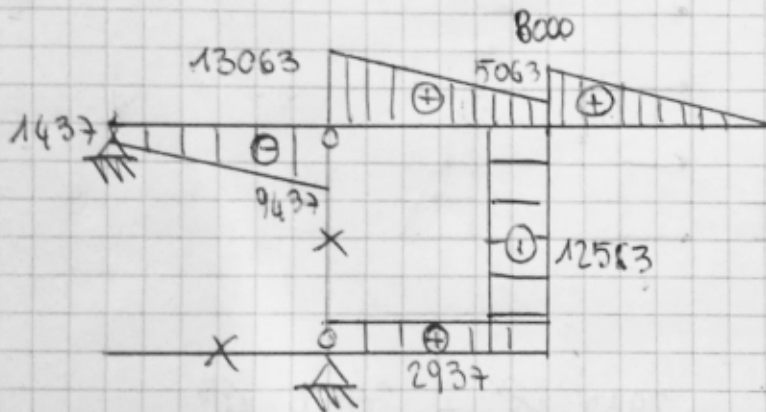
$$\begin{aligned} (1) \rightarrow & \begin{cases} M_{11} \cdot X_1 + M_{12} \cdot X_2 = -M_{10} \\ M_{12} \cdot X_1 + M_{22} \cdot X_2 = -M_{20} \end{cases} \\ (2) \rightarrow & \end{aligned}$$

$$X_1 = 22500 \text{ N}$$

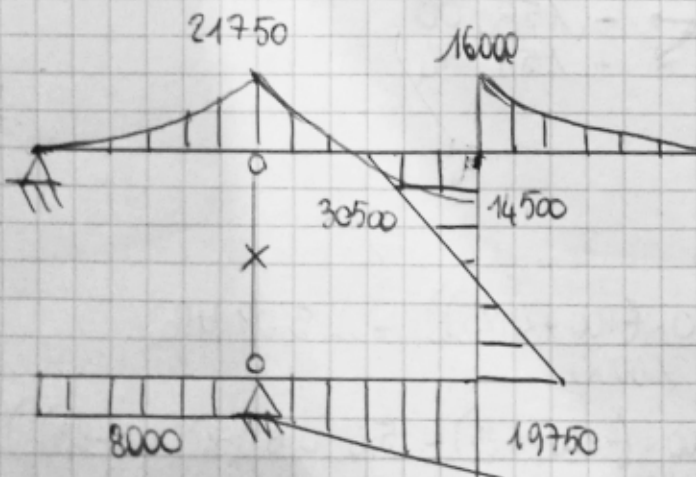
$$X_2 = -12563 \text{ N}$$



(N)



(T)



(M)

$$2) \quad M = 30500 \text{ Nm}$$

$$T = -12563 \text{ N}$$

$$N = -2937 \text{ N}$$

$$\sigma_{am} = 190 \text{ MPa}$$

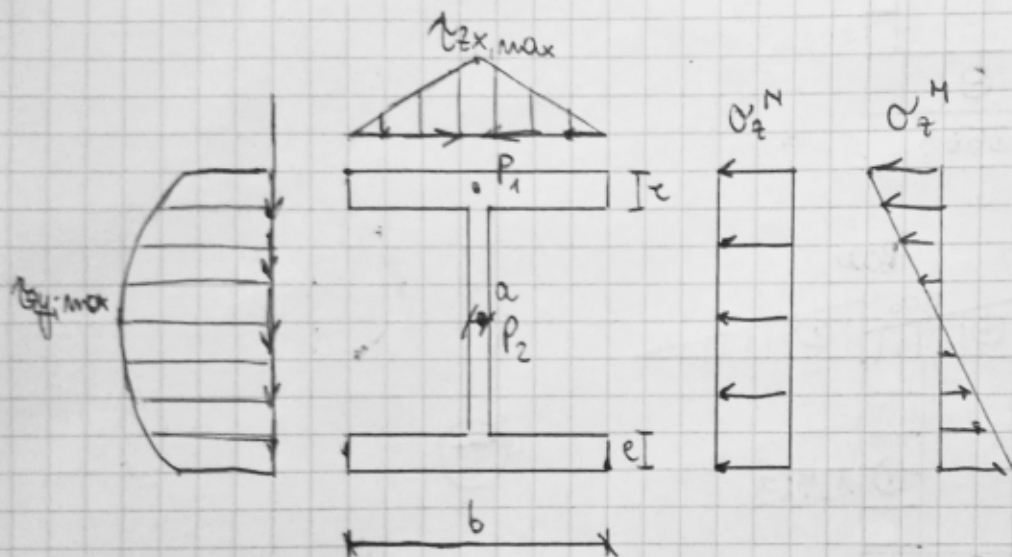
$$E = 210000 \text{ MPa}$$

$$W_{min} = \frac{30500 \cdot 1000}{190} = 160526 \text{ mm}^3$$

ADOTTO IPE 200

$$h = 200 \text{ mm} \quad b = 100 \text{ mm} \quad a = 5,6 \text{ mm} \quad e = 8,5 \text{ mm}$$

$$A = 28,48 \text{ cm}^2 \quad W_x = 194,3 \text{ cm}^3 \quad J_x = 1943 \text{ cm}^4$$



$$\sigma_z = \sigma_z^N \pm \sigma_z^M = \frac{N}{A} \pm \frac{M}{W_x} = \frac{-2937}{2848} \pm \frac{30500 \cdot 10^3}{194,3 \cdot 10^3}$$

$$= -1,03 \pm 156,97 \quad \rightarrow \quad \begin{matrix} -158,00 \\ +155,94 \end{matrix}$$

$$\tau_{zs} = - \frac{T_y \cdot S_x^*}{b_s \cdot J_x}$$

$$\tau_{zx,max} = - \frac{(-12563) \cdot (8,5 \cdot 50 \cdot (100 + 4,25))}{8,5 \cdot 1943 \cdot 10000} = -3,09 \text{ MPa}$$

$$\tau_{zy,max} = - \frac{(-12563) \cdot (8,5 \cdot 100 \cdot (-100 + 4,25) + 5,6 \cdot 0,5 \cdot (-1) \cdot (100 - 8,5)^2)}{5,6 \cdot 1943 \cdot 10000} = -12,10$$

$$= -12,10 \text{ MPa}$$

$$\sigma_{id,p_1} = \sqrt{158^2 + 3 \cdot 3,09^2} = 158,09 \text{ MPa} < 190 \text{ MPa} \quad \text{OK!}$$

$$3) \quad M_{11}^N = \frac{1}{EA} \int_0^l x^2 dz = \frac{l}{EA}$$

$$M_{11}^{TOT} = M_{11} + M_{11}^N$$

$$(1) \rightarrow \begin{cases} L_{VE} = 0 = L_{V1} = M_{11}^{TOT} \cdot X_1 + M_{12} \cdot X_2 + M_{10} \end{cases}$$

$$(2) \rightarrow \begin{cases} L_{WE} = 0 = L_{W1} = M_{12} \cdot X_1 + M_{22} \cdot X_2 + M_{20} + \frac{1}{K} \left(\frac{19}{4} q l + X_2 \cdot 1^* \right) \end{cases}$$

$$K = 1000 \frac{N}{mm}$$

$$X_1 = 20205 \text{ N}$$

$$X_2 = 13997 \text{ N}$$

